PAUL SCHERRER INSTITUT

PSI

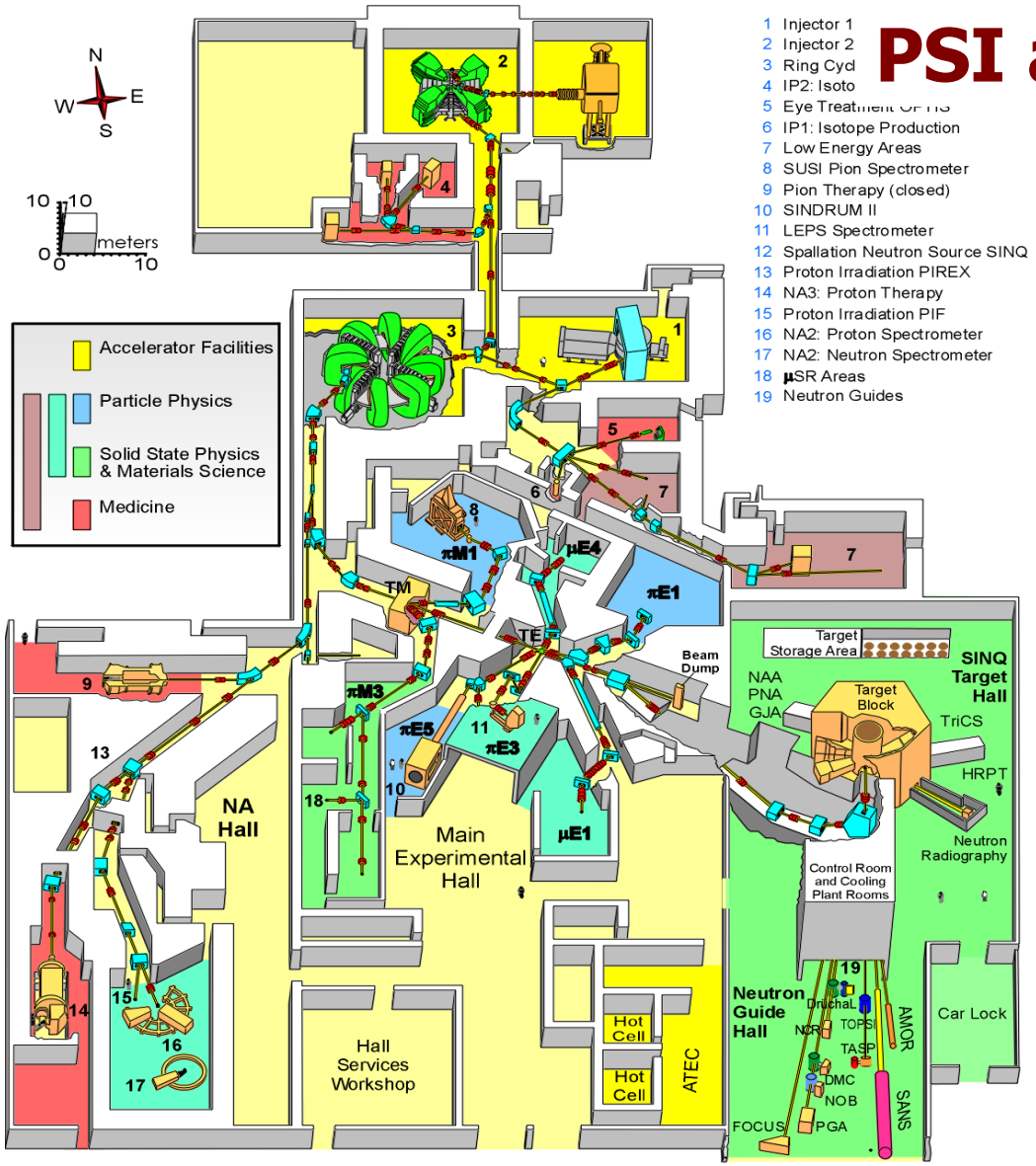
Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

RadWaste Analytics

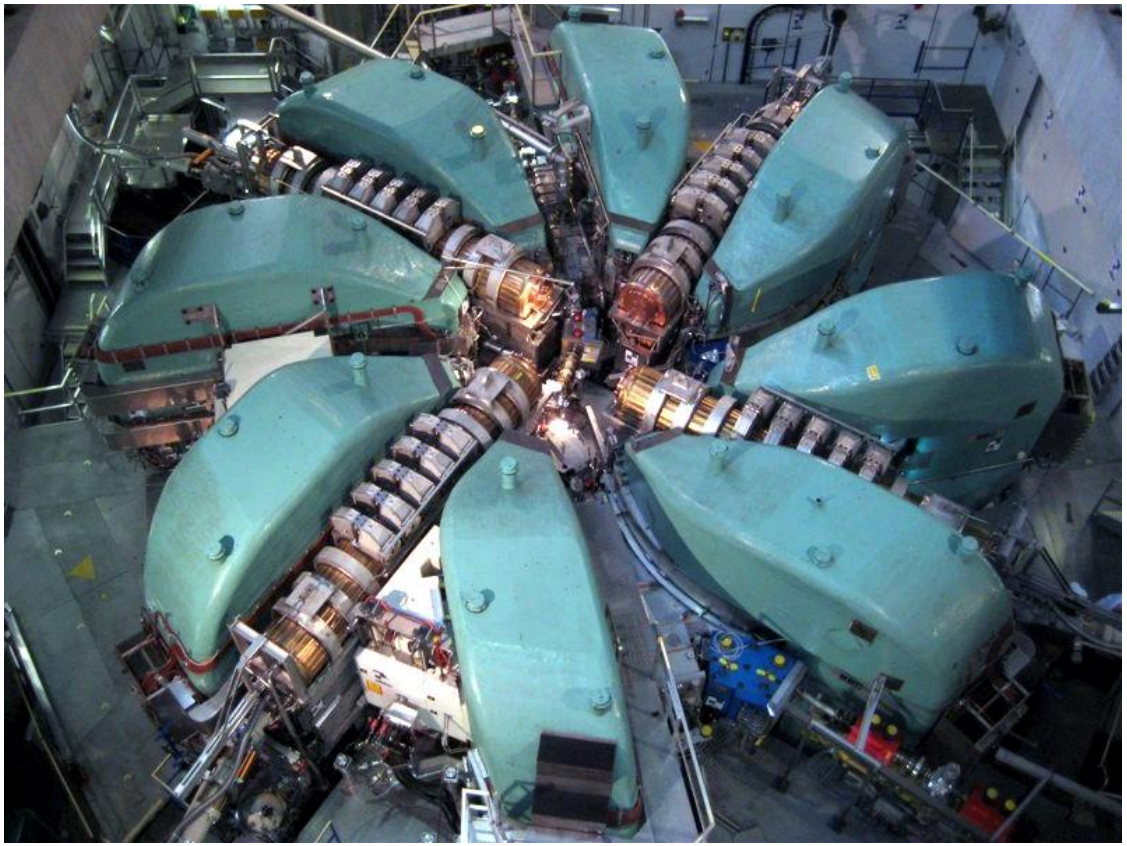
Marin Ayranov

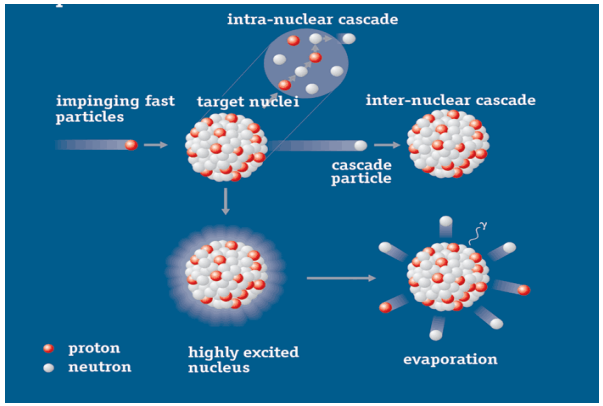
PSI accelerator facilities

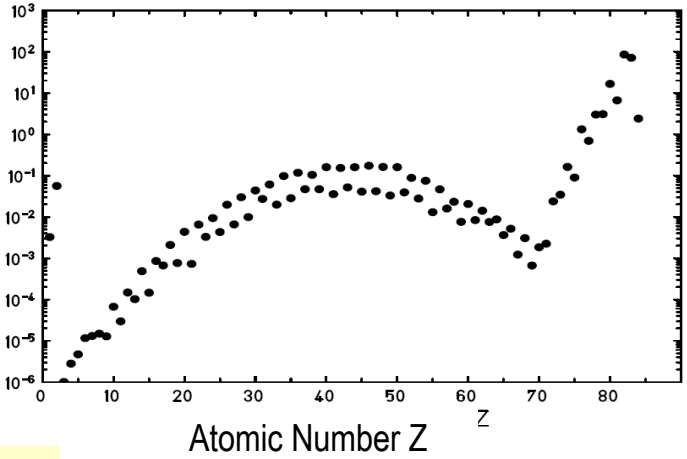


- Injector cyclotron (72 MeV protons)
- 590 MeV Ring Cyclotron
- Up to 3.2 mA proton beam current
- SINQ – spallation neutron source
- COMET (cyclotron 250 MeV) for medical use
- Ultra Cold Neutrons
- SLS Swiss Light Source

Spallation Reactions
High Energy Accelerator Facilities

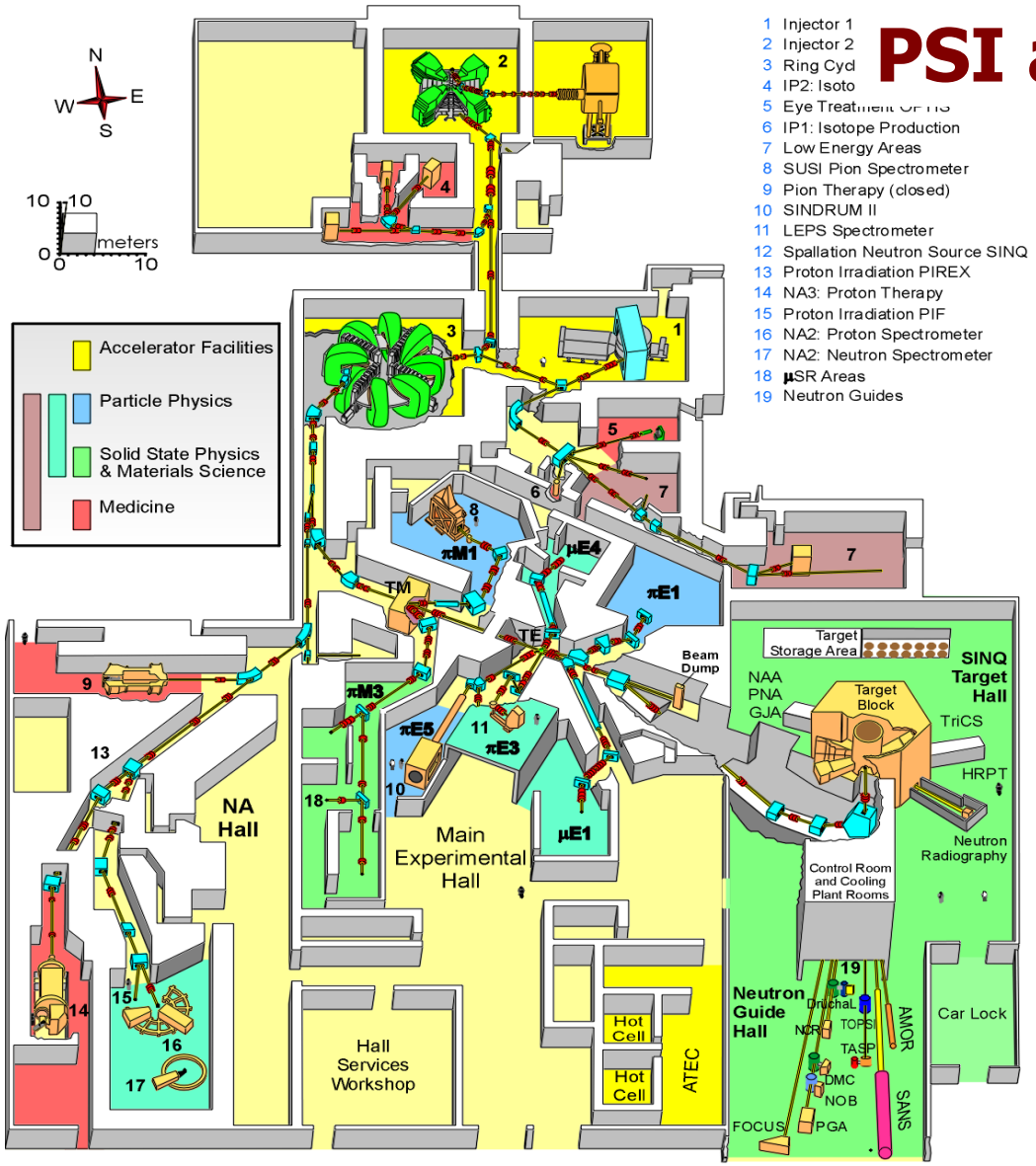






All elements of periodic table with $Z \leq Z_{target} + 1$

PSI accelerator facilities



Activated parts:

SINQ target, BMA-Target, Beam dumps, Target E, Collimators, Shielding etc.

Materials:

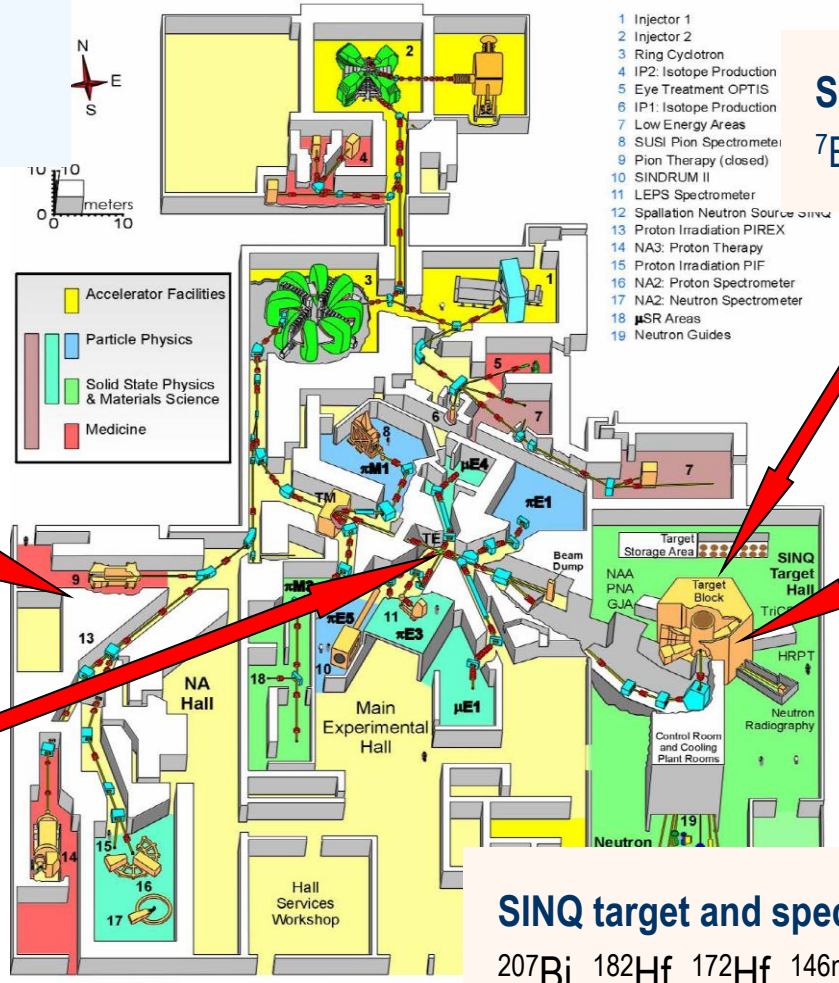
Zirkalloy, Lead, Aluminium, Stainless steel, Copper, Tungsten, Beryllium, Cast iron, Graphite, Concrete, SINQ Cooling Water etc.

ERAWAST

Exotic Radionuclides from Accelerator WAstes for Science and Technology

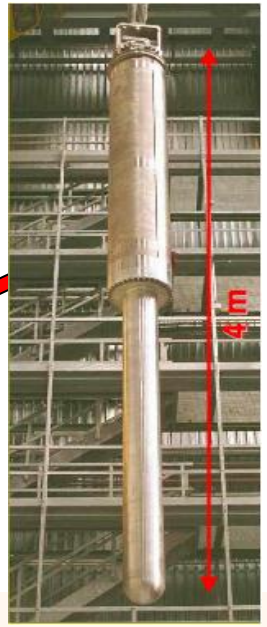
Copper beam dump

^{44}Ti, ^{53}Mn, ^{26}Al, ^{60}Fe, ^{59}Ni, ^{32}Si



SINQ cooling water

^{7}Be, ^{54}Mn, ^{22}Na, ^{88}Y, ^{110m}Ag



Target E

^{3}H, ^{14}C, ^{10}Be

SINQ target and special irradiation

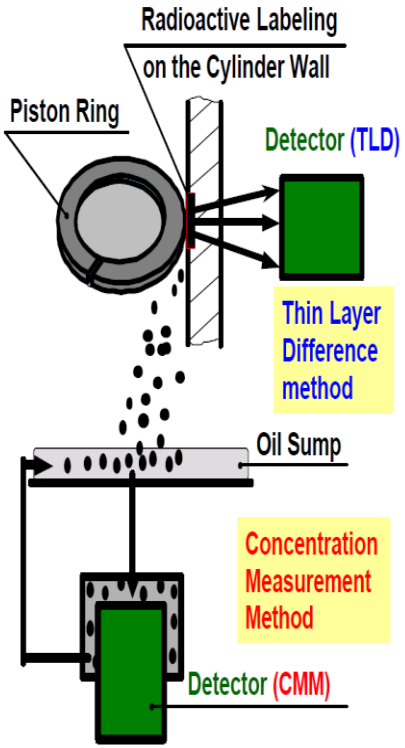
^{207}Bi, ^{182}Hf, ^{172}Hf, ^{146m}Sm, ^{148}Sm, ^{148}Gd, ^{44}Ti,

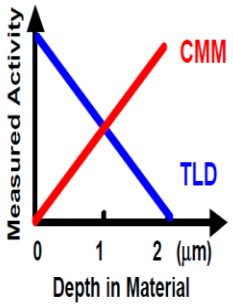
^{205}Pb, ^{129}I, ^{36}Cl, ^{108m}Ag, Dy isotopes

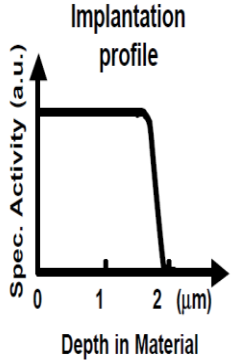
Application Examples

- ^{7}Be for studies of ^{7}Be(p, γ)^{8}B and ^{7}Be(n, α)α nuclear reactions
- ^{7}Be mass bias calibration standard for ^{10}Be half-life
- ^{7}Be high sensitivity wear measurements and determination of the decay rate in host materials
- ^{10}Be for RIMS and AMS
- ^{26}Al basic astrophysics experiments
- ^{60}Fe measurement of half-life, neutron capture cross section and isotopic anomalies observed in manganese crusts
- ^{53}Mn – half-life AMS measurement
- ^{146m}Sm - half-life determination
- ^{207}Bi – gamma calibration standard
- ^{44}Ti - core collapse supernovae
- ^{44}Ti/^{44}Sc radioisotope generator for nuclear medicine application

^{7}Be for wear analysis







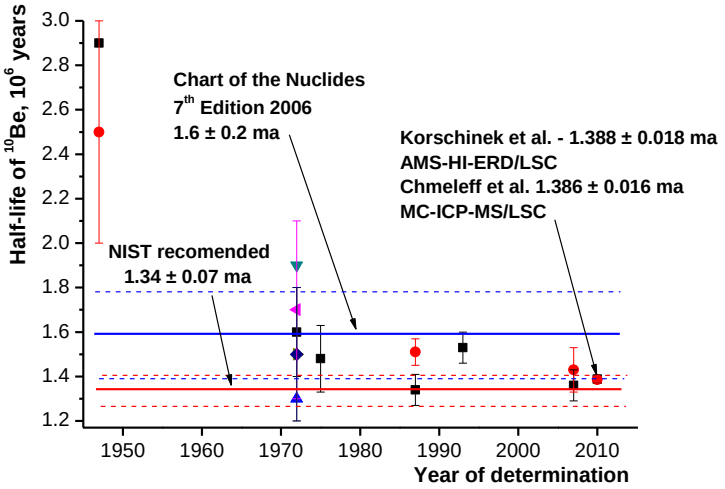
Material	Density g/cm3	Wear rate µm/10^6 cyc.	Implant. depth in µm at beam energy of: 60 keV	260 keV	1.2 MeV	6 MeV	15 MeV
UHMWPE	0.97	50	0.36	1.1	2.9	13	43
Ti	4.52		0.17	0.56	1.5	6.1	18
CoCrMo	8.28		0.11	0.39	1.1	4.1	12
Alumina	3.1	0.15	0.20	0.59	1.6	6.7	21
Zirconia	5.5		0.15	0.48	1.3	5.3	16

In-vivo use: ≈10^6 cycles/year

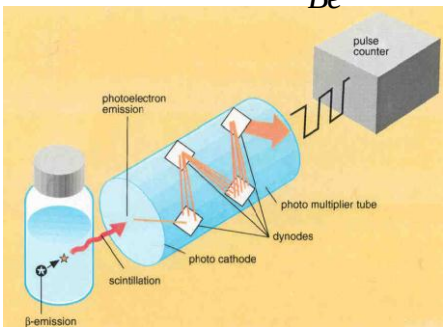
Simulator runs: (2-10)•10^6 cycles

Required dose: some pnA per cm^2 (e.g. ball of 22-28 mm diameter)

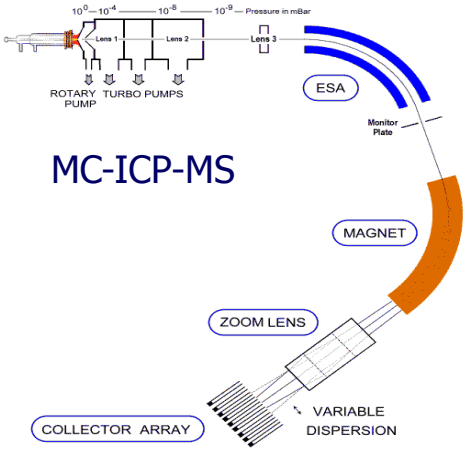
^{10}Be Half-life



$$T_{1/2\,^{10}Be} = \frac{N_{^{10}Be}}{A_{^{10}Be}} \ln 2$$



LSC



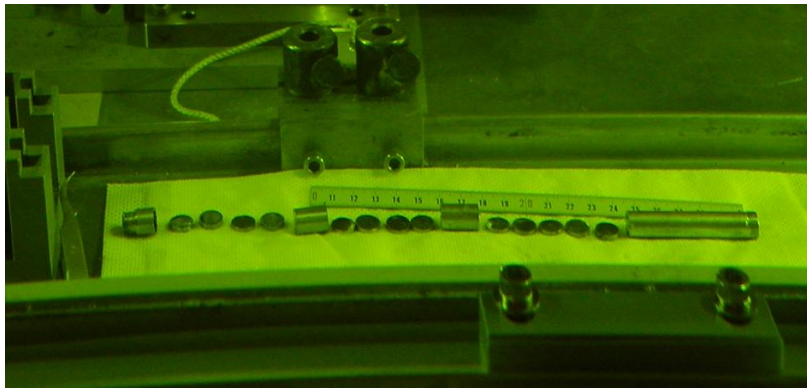
MC-ICP-MS

- ICP-MS can measure isotope ratios for the Beryllium isotopes BUT – only one stable Be isotope - **^{9}Be**
- **Second point for mass bias correction - ^{7}Be**

Measurement of the Cross Section of the ^{7}Be(n,α)α Reaction and the Problem of Primordial ^{7}Li

Project in collaboration with ISOLDE - CERN, SARAF - Soreq Nuclear Centre,

Argonne National lab, University of Connecticut, Hebrew University and Weizmann Institute



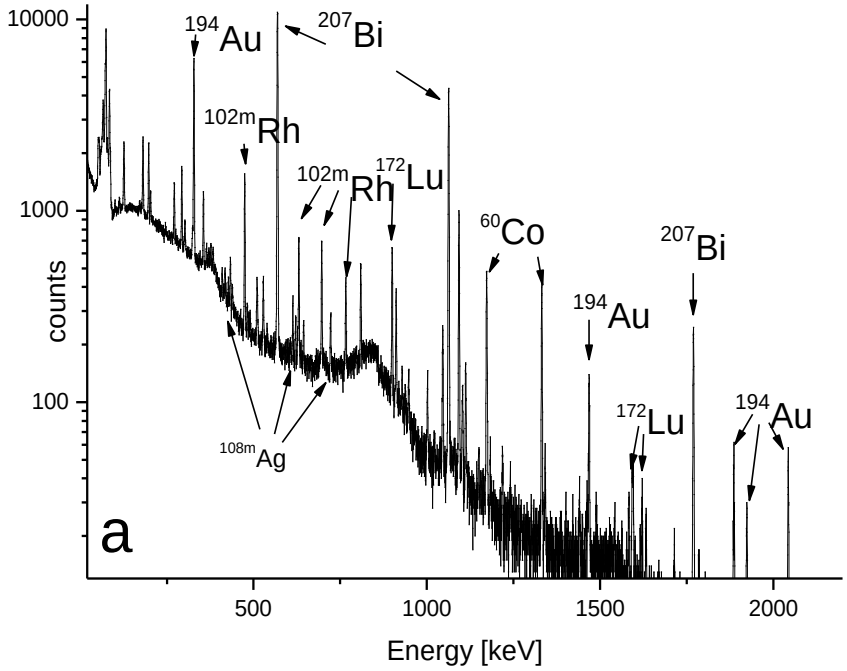
^{207}Bi - Calibration source

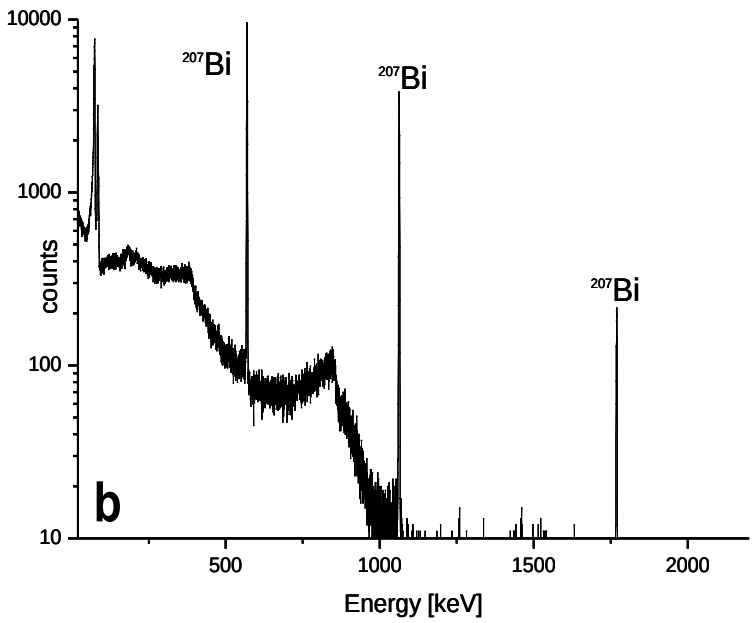
Application as γ-spectroscopic
-calibration
-source (240 kBq)

- relatively long half-life of 31.5 ys
- three γ-lines up to 1800 keV

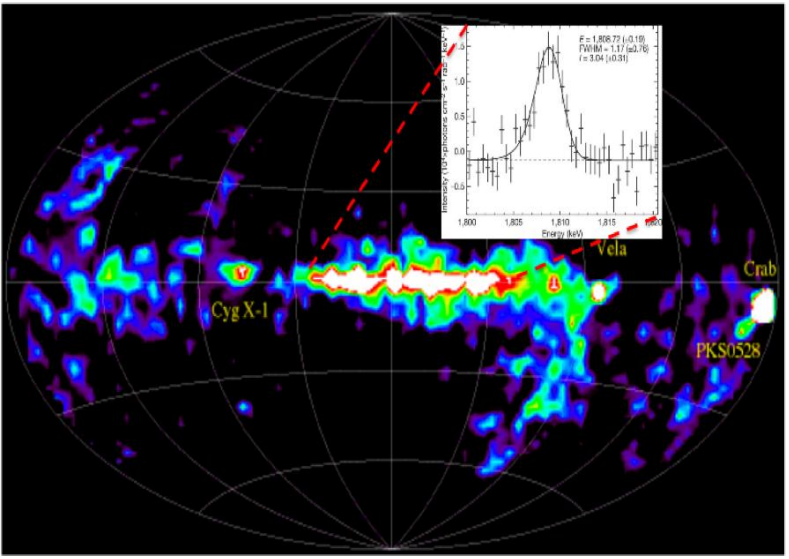
Chemical separation of ^{207}Bi

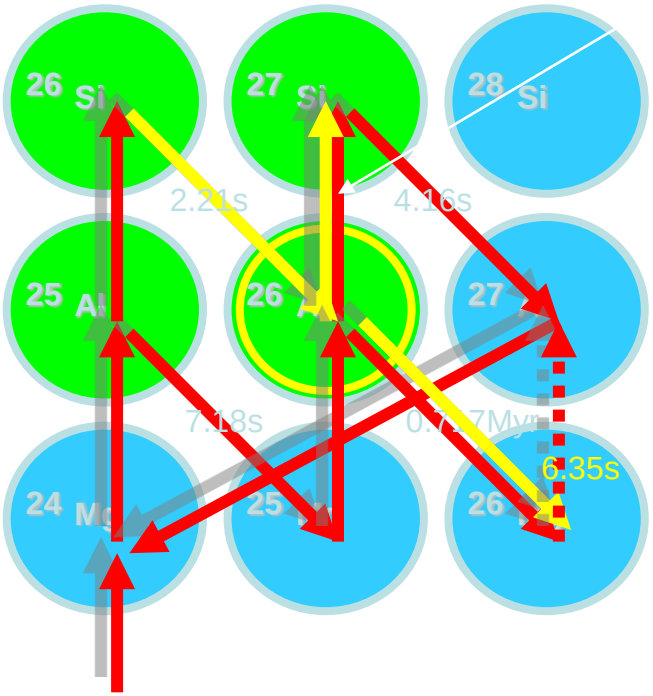
10 mg of irradiated Pb before, (spectrum a) and after chemical separation, (spectrum b) .

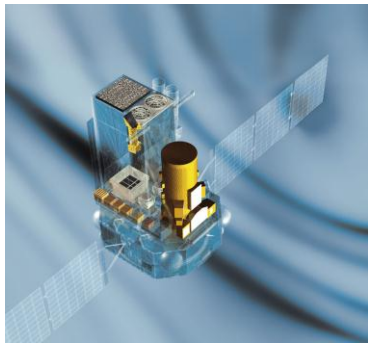




^{26}Al(n,p) and ^{26}Al(n,α) reaction rates are critical for ^{26}Al processed by explosive and convective burning in massive stars and ejected into the ISM by core collapse supernovae







^{60}Fe half-life and neutron capture cross section

^{60}Fe horizon at 2.8 Ma

- Based on

  ^{10}Be $t_{1/2}$ = 1.51 Ma

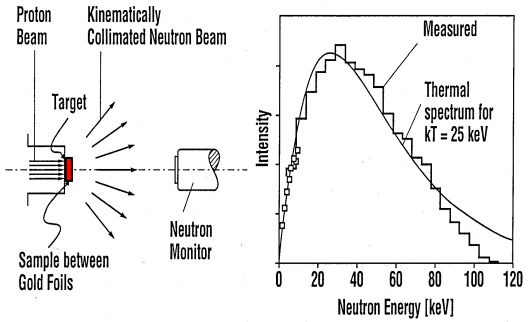
Produced by Super Nova

40 pc distance from Earth

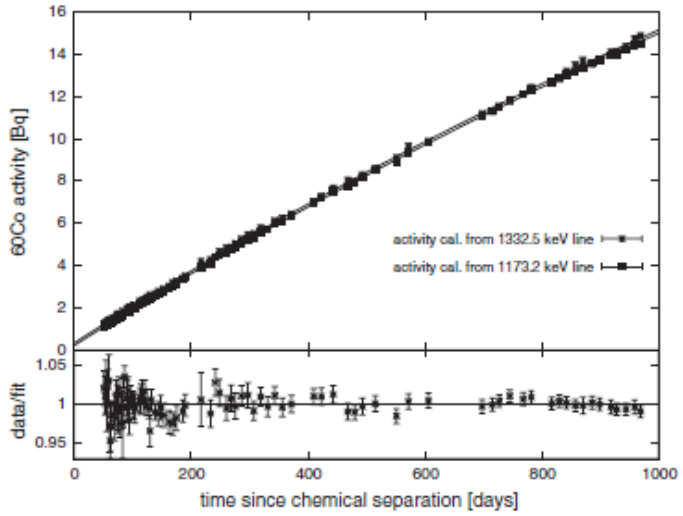
- Based on

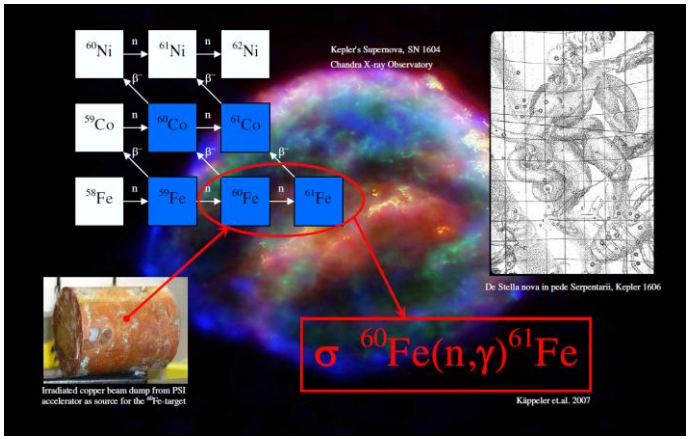
  ^{60}Fe $t_{1/2}$ = 1.49 Ma

Physical Review Letters, 93 2004



‹σ› = 10.2 ± 2.9 mbarn

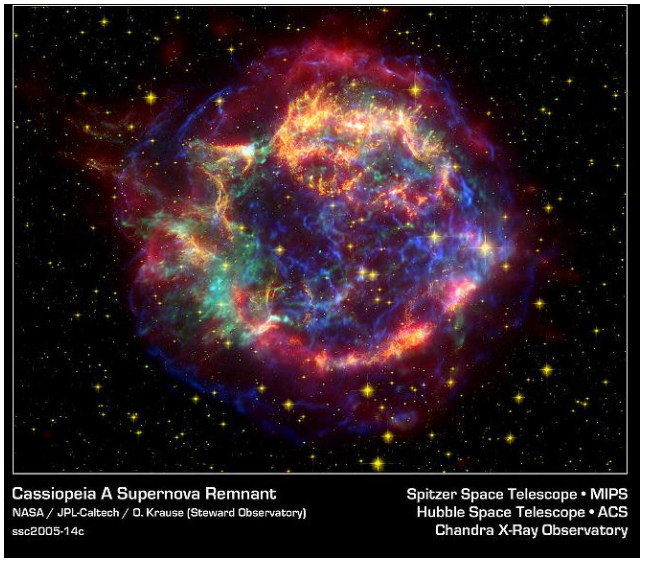




$T_{1/2}$ = 2.62 ± 0.04 · 10^6 years

Physical Review Letters, 102 2009
Physical Review Letters, 103 2009

Core Collapse Supernovae



Explosion mechanism is extremely complex

Good diagnostic – **^{44}Ti**

Produced in significant quantity

Gamma-ray observable – 1157 keV

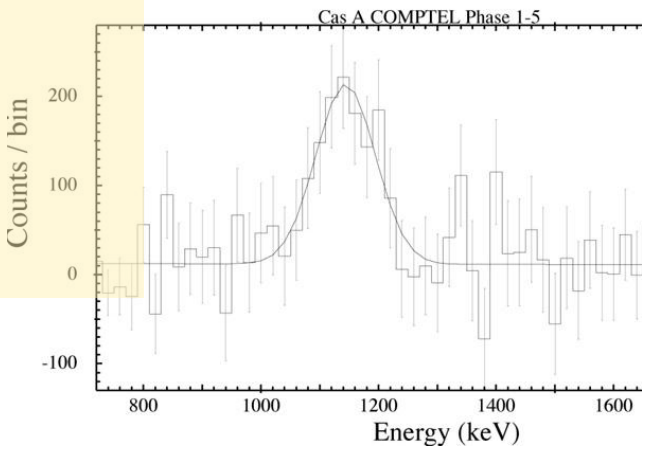
Quantity produced is sensitive to underlying physics

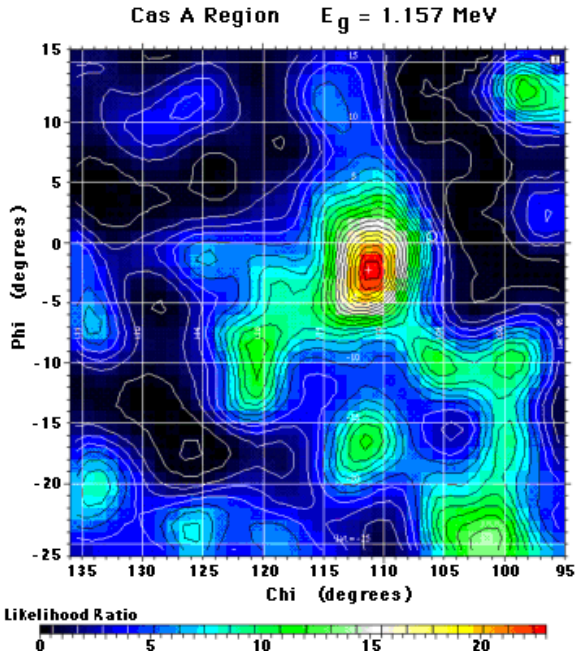
^{44}Ti abundance determined by only a few key reactions:

^{40}Ca(α,γ)^{44}Ti

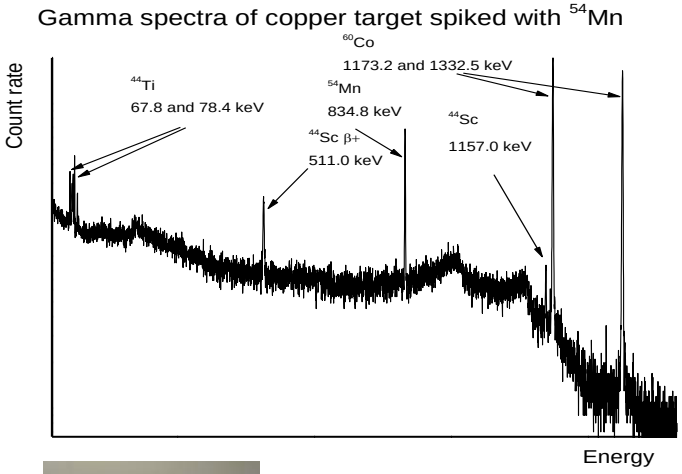
^{44}Ti(α,γ)^{48}Cr

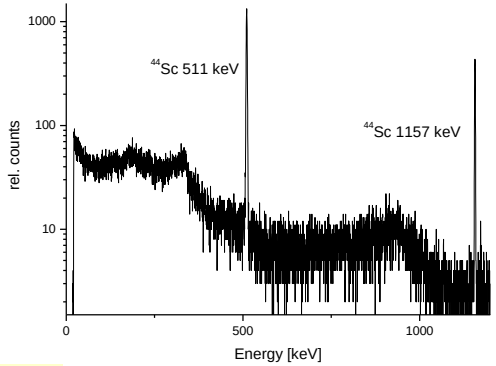
^{44}Ti(α,p)^{47}V





Biomedical application



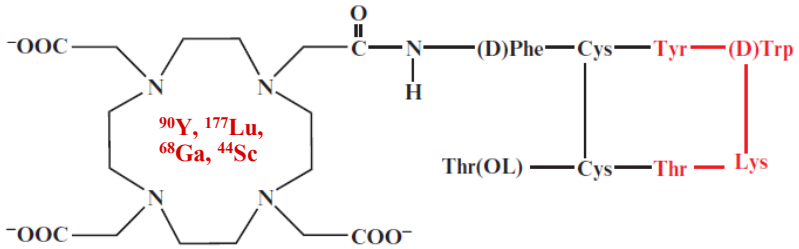


^{44}Ti/^{44}Sc generator system
DOWEX 1x8 and
0.06 M HNO_3/0.4 M HF

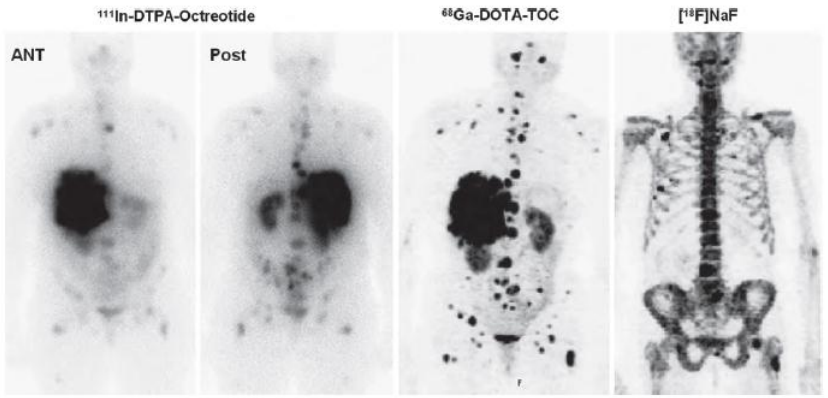
Gamma spectrum of
^{44}Sc eluate

DOTA-Octreotide (DOTA-TOC)

^{177}Lu, ^{90}Y - therapy
^{68}Ga, ^{44}Sc - diagnostic



M. Pruszynski et al. J Nicl Med Supp 2 (2010)



Gabriel M. et al. J Nucl Med 48 (2007)

THANK YOU FOR YOUR ATTENTION!